The Dynamics of Turbulence and Flow During the L-H Transition

by

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Motivation

- **Understanding the L-H transition trigger mechanism is essential for fusion**
  - Achieving H-mode will be critical to ITER
  - Need to understand the role of microscopic edge turbulence and flow dynamics

- **Theory predicts turbulence driven shear flow plays a critical role to the L-H transition**

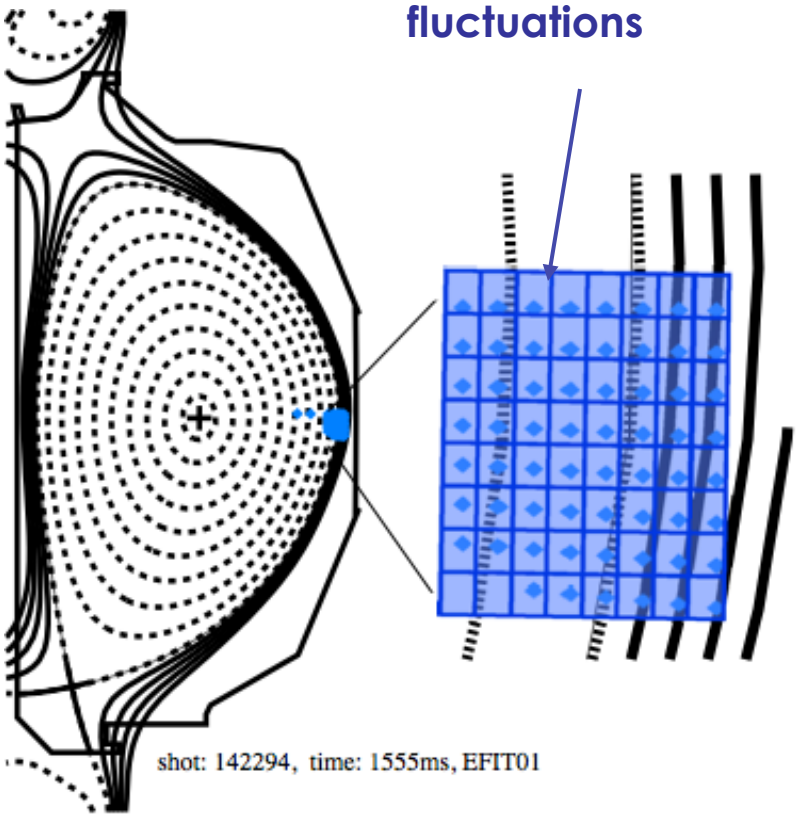
- **Requires detailed turbulence and flow dynamics examination in the edge region before, during and after the L-H transition**

L-H Transition Obtained with Heating Power just above the L-H Transition Power Threshold

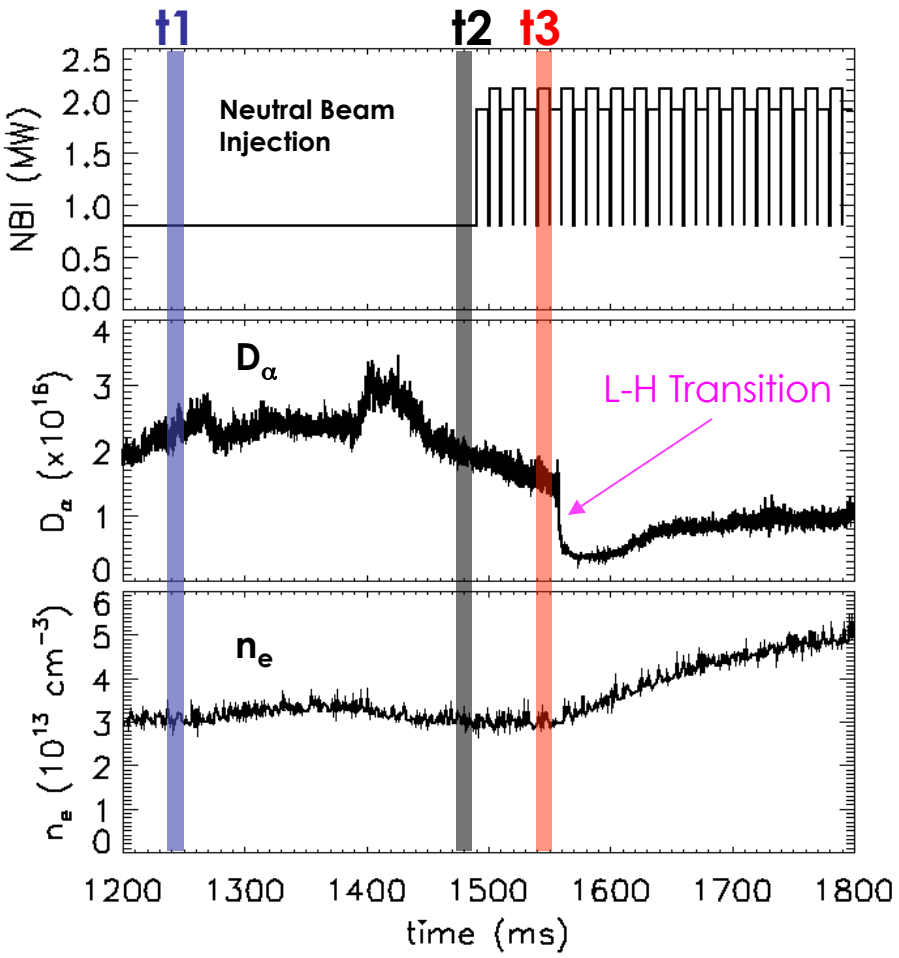
- **LSN plasma shape (∇B towards X-point)**

- **Long wavelength density fluctuations are measured with high sensitivity 2D Beam Emission Spectroscopy (BES) array ($k_\perp \rho_i$<1)**
  - $\tilde{n}/n$
  - V_θ, V_r
  - Turbulence decorrelation rate
  - Correlation length

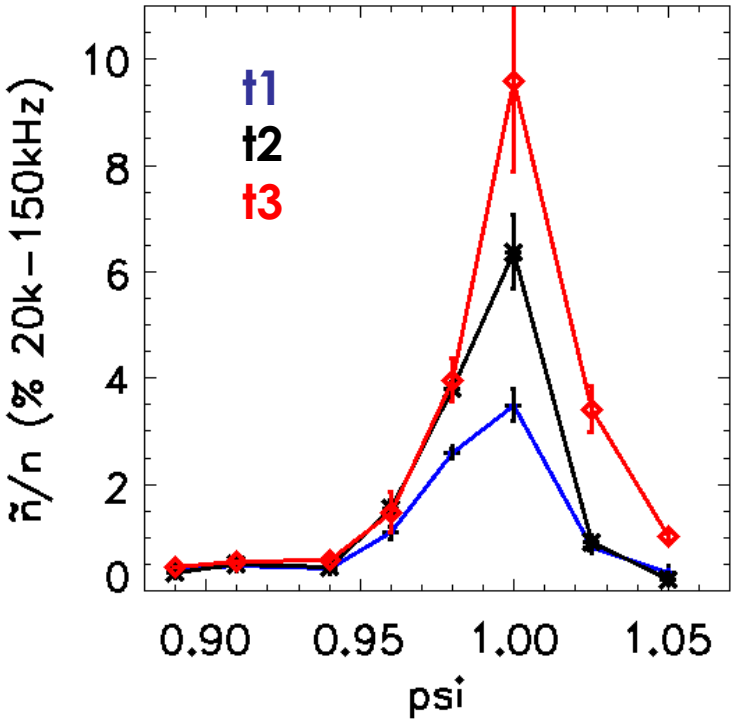
2D BES array measuring density fluctuations



Turbulence Increases with Time and Power Approaching L-H Transition

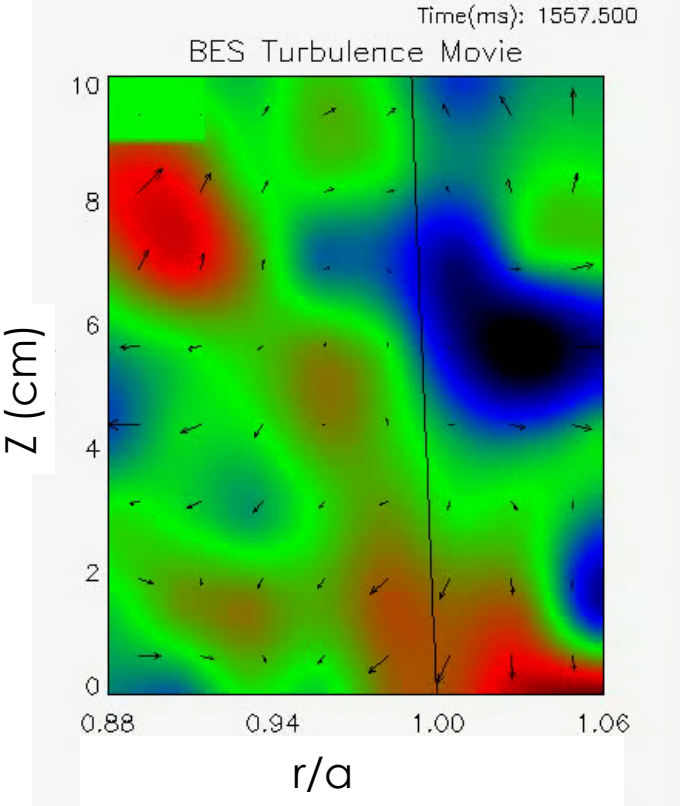


Frequency Integrated over 20k-150kHz $\tilde{n}/n$ amplitude



Turbulent Velocity Fluctuation Measured from Image-based Velocimetry

- **Vector-matching frame by frame to infer short time scale velocity fluctuation [1]**
  - Over 10 ms time window
- **With inferred $\tilde{v}_\theta$ and $\tilde{v}_r$**
  - Calculate velocity fluctuation spectrum $S(\tilde{v}_\theta)$
  - Infer Reynolds stress, in principal proportional to the electrostatic Reynolds stress $\langle \tilde{v}_r \tilde{v}_\theta \rangle$



Refer to G.McKee's poster on Thursday

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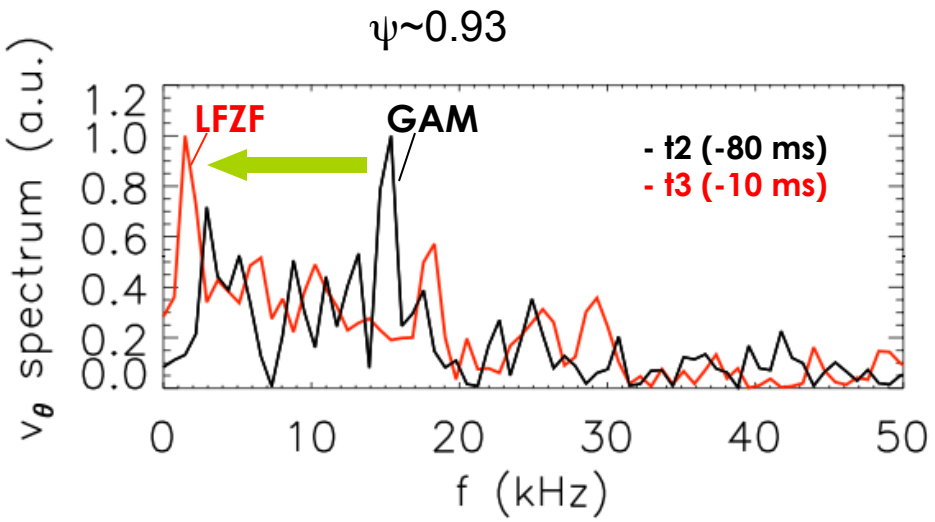
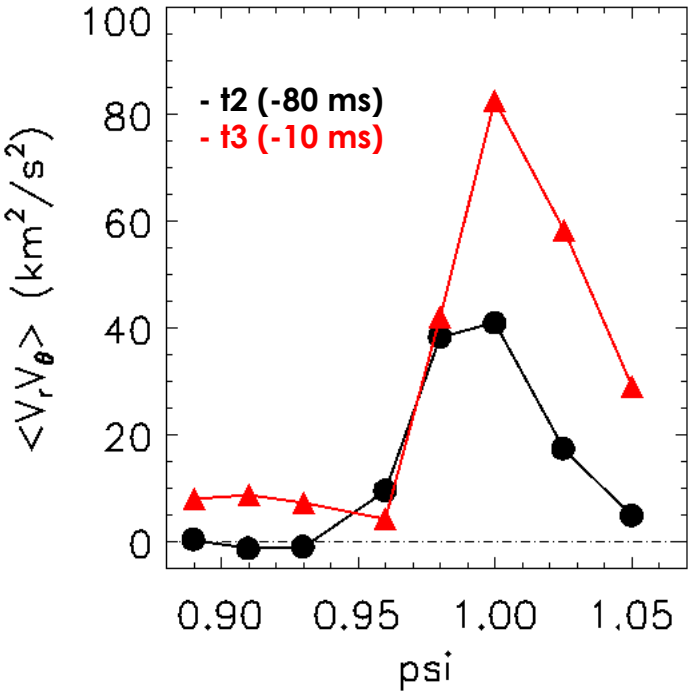
[1] G. McKee, et al., RSI, 75, 3490, 2004

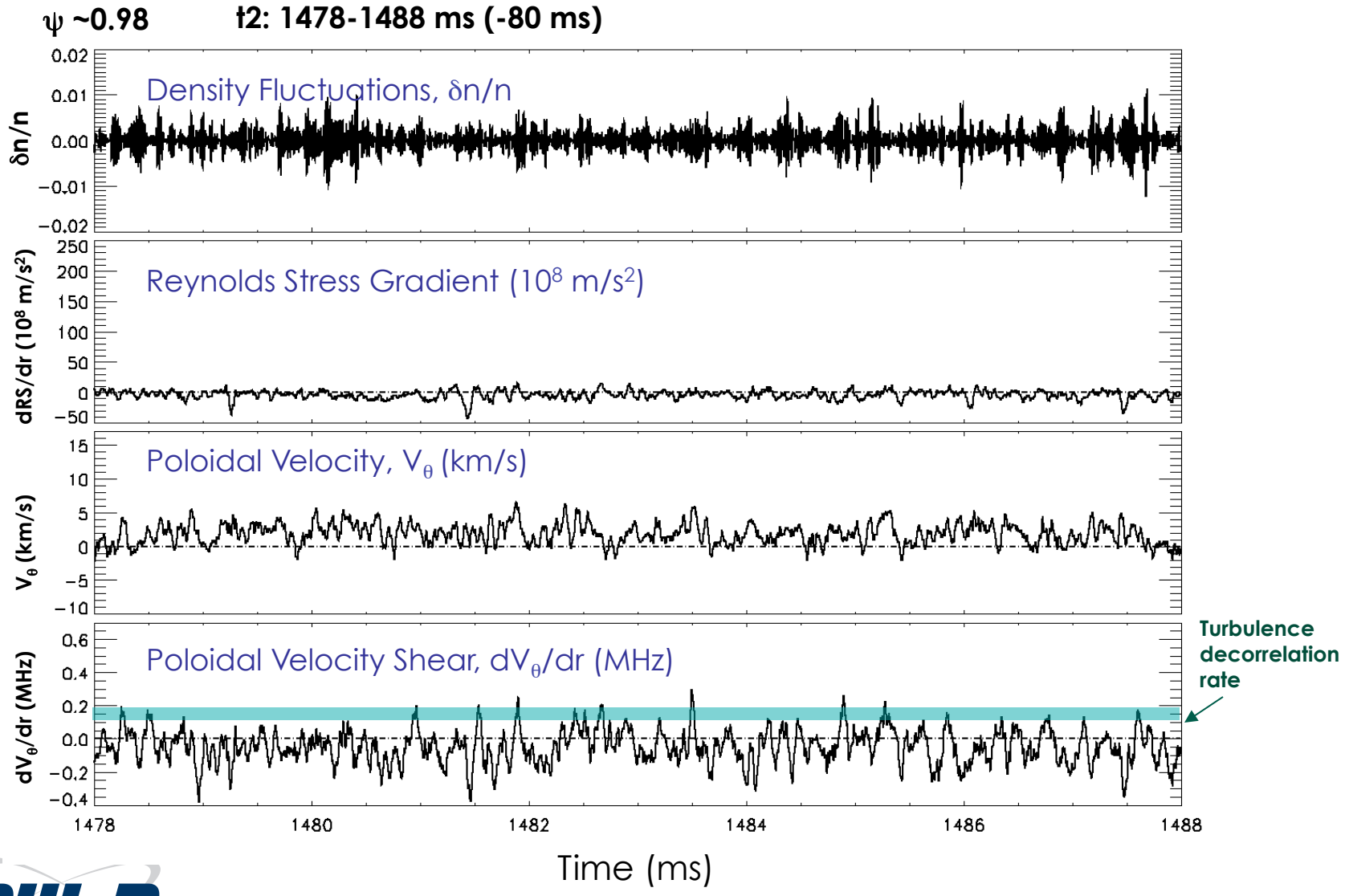
Turbulence Flow Changes from GAM Dominant to LFZF Dominant Approaching the Transition

- **GAM- Geodesic Acoustic Mode**
  LFZF - Low Frequency Zonal Flow
- **Reynolds stress increases approaching the L-H transition**
  - Consistent with the observation of the increased LFZF





Large Increases in the Turbulence and Flow Shear Approaching the L-H Transition



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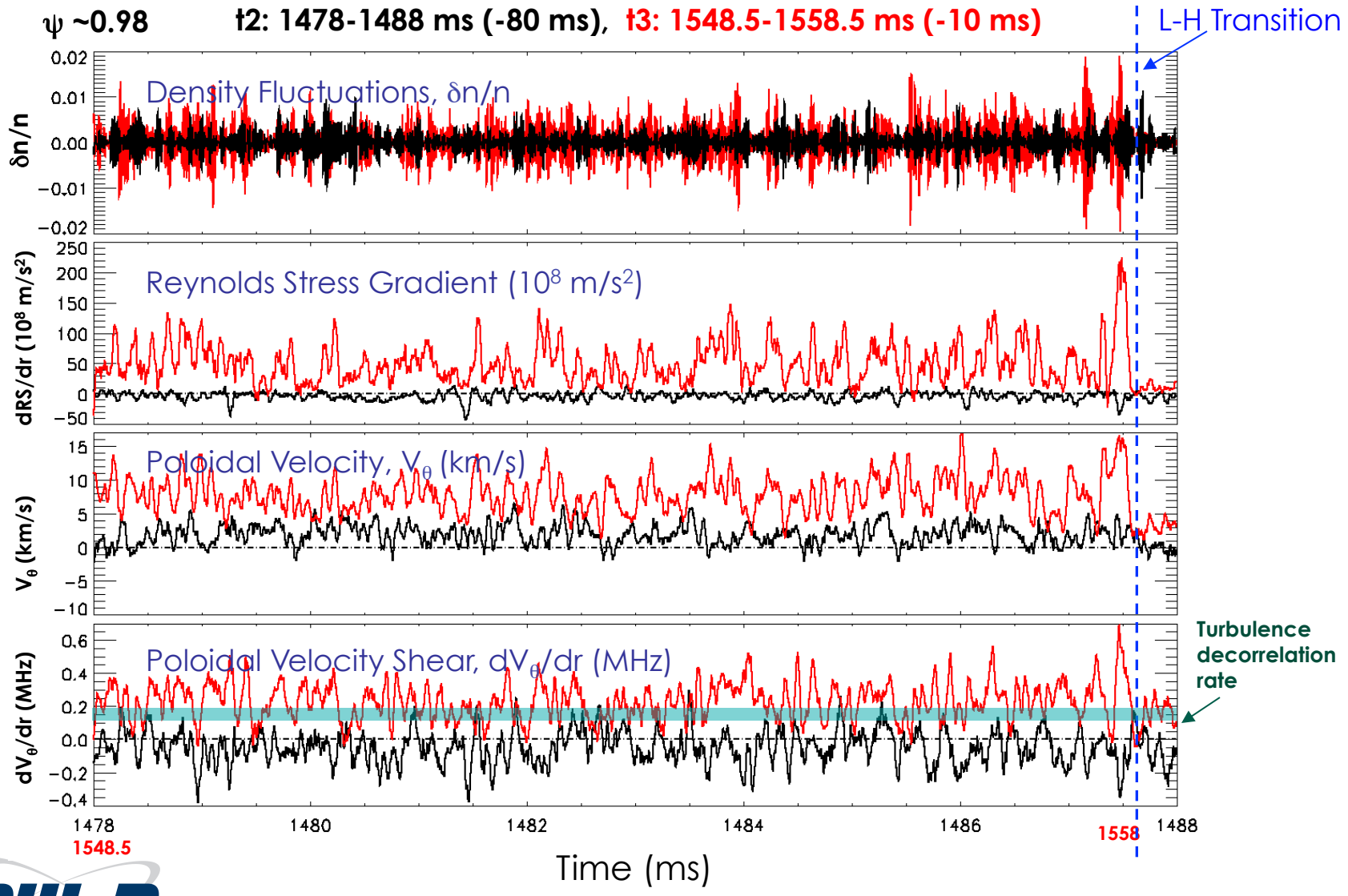

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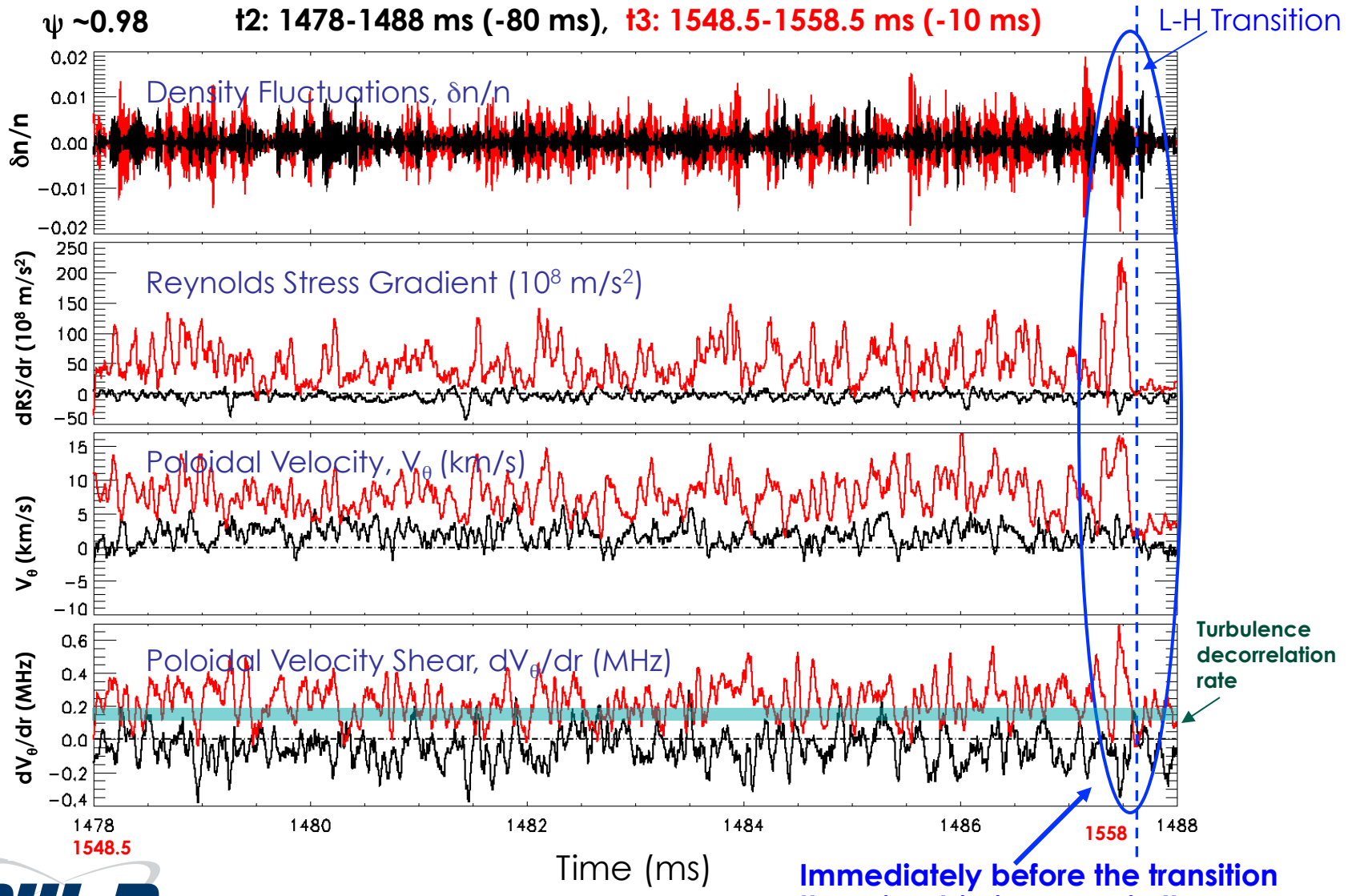

Immediately before the transition there is a big increase in the turbulence and flow shear.

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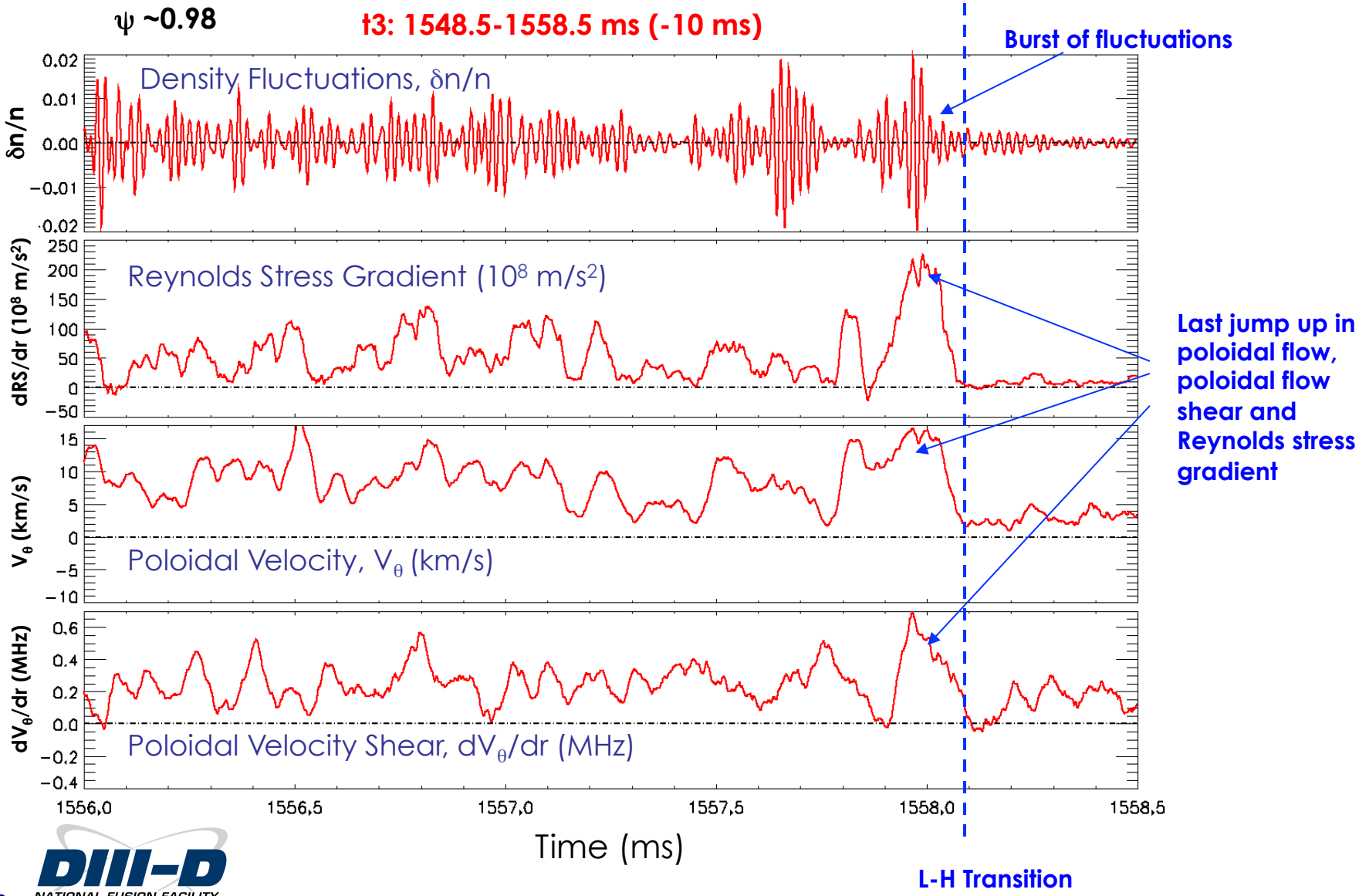
Increased Turbulent Flow Shear Appears to Trigger the L-H Transition



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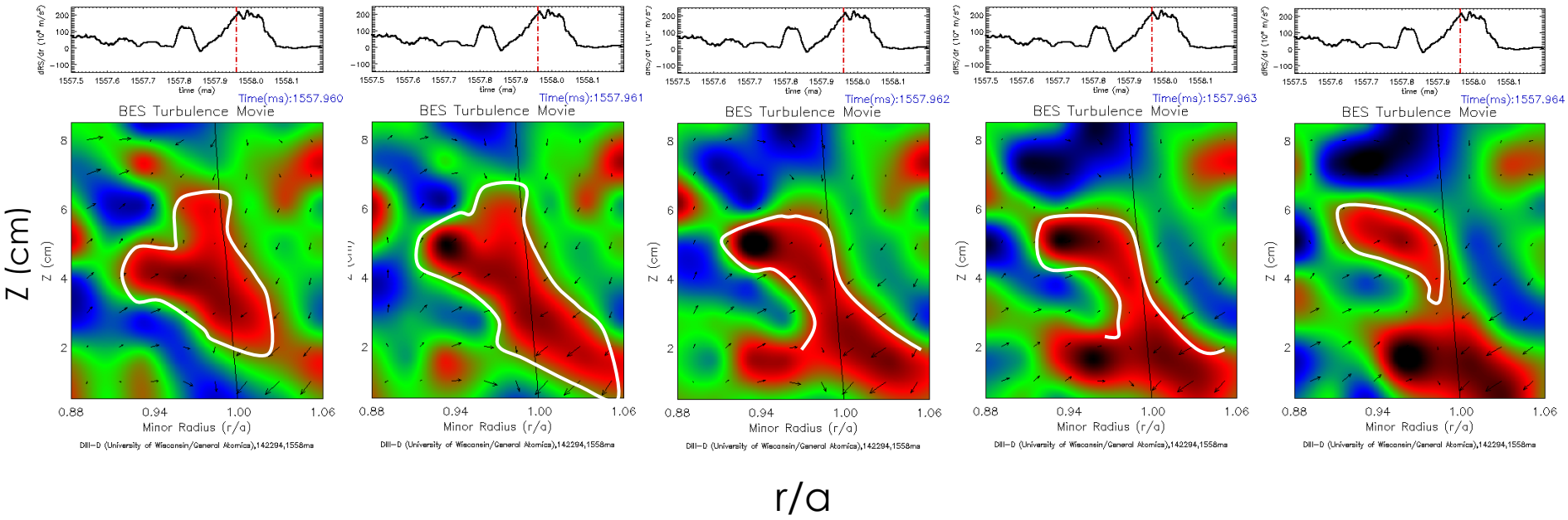
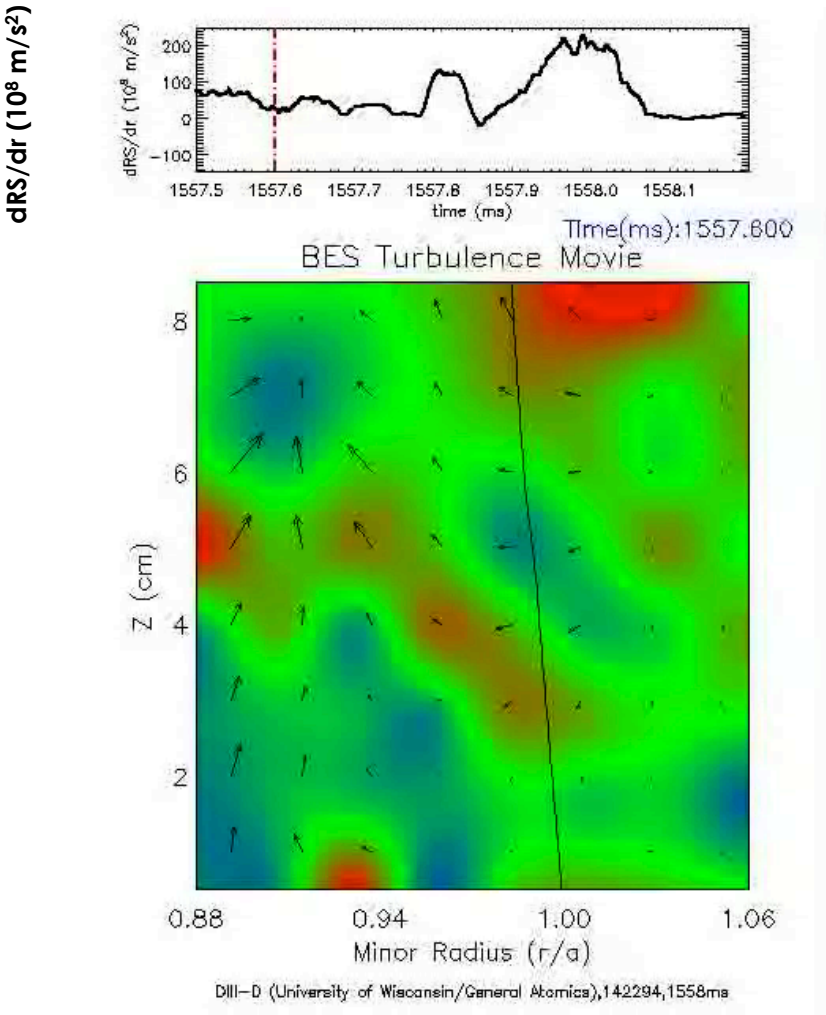
2D Imaging Showing Stronger Turbulence Eddy Tilting and Stretching

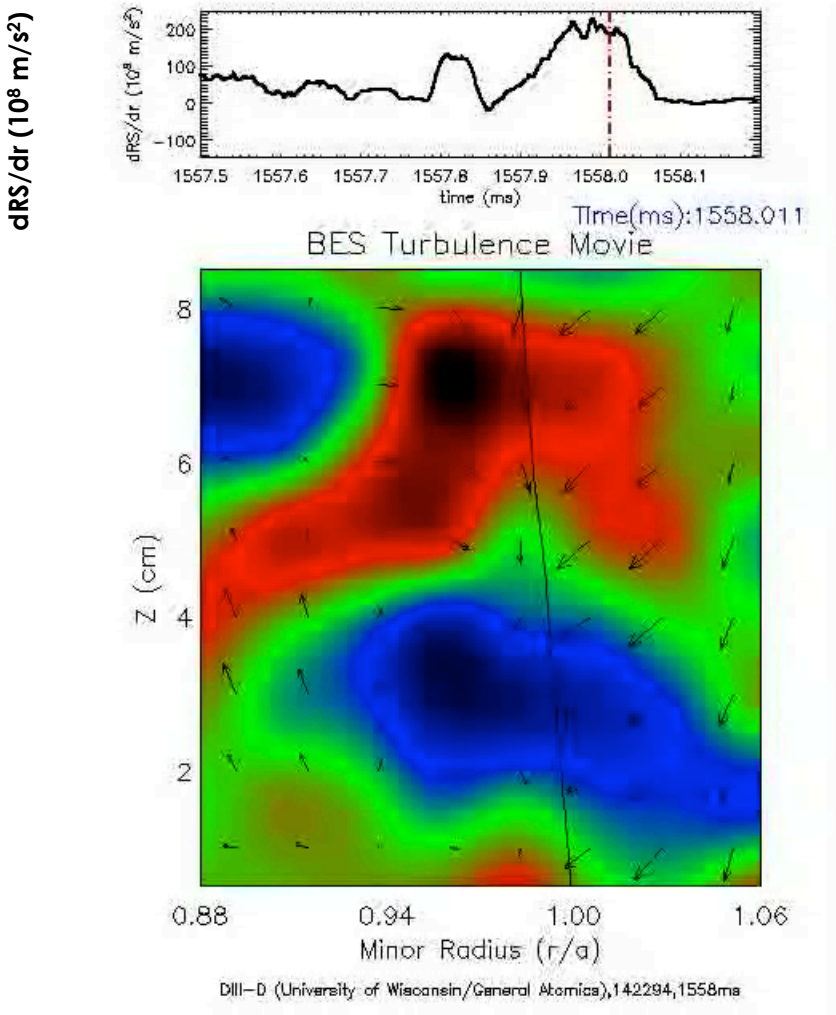
- **Turbulent eddies are stretched, tilted and torn apart**



2D Imaging Showing Stronger Turbulence Eddy Tilting and Stretching

- **Turbulent eddies become more rigorous, stretched and tilted immediately before L-H transition**
  - Consistent with the jump up of the Reynolds stress





Summary

- **Density fluctuation amplitudes increase with time and input power approaching the L-H transition**
- **Inferred Reynolds stress and Reynolds stress gradient increase approaching the L-H transition**
  - Turbulence equilibrium poloidal flow changes from GAM dominant to LFZF like dominant approaching the transition
- **Immediately before the transition turbulence amplitudes, Reynolds stress gradient and flow shear increase largely**
- **Taken together, the observations are consistent with the picture that the increased power flux leads to increased turbulence, turbulent Reynolds stress, shear flow development, and a rapid changing edge flow that triggers the transition**
- **Future work**
  - Mean E_r evolution right before L-H transition
  - Macroscopic scaling of L-H transition power threshold and relation to the microscopic turbulence dynamics